

The University of Chicago

THE GEOLOGY AND MINERAL RE-
SOURCES OF THE STREATOR
QUADRANGLE, ILLINOIS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1935

By

LEWIS CASS ROBINSON

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CHAPTER I

INTRODUCTION

Location and Extent of the Area

The Streator quadrangle includes the southeastern part of La Salle County and the northwestern part of Livingston County, Illinois. It lies about ninety miles southwest of Chicago and about fifty miles east of Peoria. Streator, about sixteen miles due south of Ottawa, is situated approximately in the center of the quadrangle. The area is 15 minutes of longitude in width, lying between 88 degrees and 45 minutes and 89 degrees west longitude, and is 15 minutes of latitude in length, lying between 41 degrees and 41 degrees and 15 minutes north latitude. The boundaries, which disregard township, section, and county lines, include about 221 square miles.

Purpose of the Report

This report presents geological information concerning the present and potential mineral resources of the area to those who are interested in the economic or educational possibilities of the area. Coal, clay, shale, sand, cement, and gravel are produced in the Streator quadrangle or in the areas immediately adjacent. Ground water supplies are a necessity; and productive soils make up an important mineral resource. Also the geologic history of the area is of importance to teachers, students, and residents.

Acknowledgments

Mr. Bert Millington, Mr. Robert Beck, and Mr. Joseph H. Mills served as field assistants during the summers of 1932, 1933, and 1934, respectively, when the field work on the Streator quadrangle was done.

The writer wishes to acknowledge his indebtedness to several members of the Illinois State Geological Survey, particularly to Dr. George E. Ekblaw for his suggestions and criticisms during the investigation of the area, and to Dr. Marvin Weller and Dr. H. Bowman Willman and Dr. Gilbert H. Gady in regard to

the Pennsylvanian stratigraphy, and to Mr. Louis E. Workman in regard to older formations. Dr. Gilbert H. Cady supplied information concerning the coal resources of the area and Mr. G. E. Lamar supplied information concerning the non-fuel mineral resources.

Members of the Department of Geology of the University of Kentucky offered many helpful suggestions; particularly is the author indebted to Mrs. Louise Barton Freeman, Mr. Joseph H. Mills, and Mr. Herbert Parker for their assistance in the preparation of faunal lists and their mechanical analyses and mineral determinations in sedimentary petrography.

The co-operation of those engaged in well drilling, coal mining, and the shale industries, particularly Mr. F. H. Rentz, Streator City Engineer, is gratefully acknowledged.

CHAPTER V

GEOLOGIC HISTORY

The character of the bed rock, the surficial deposits, and the topography present in a given area record the geologic history of that region. The character of the rock formations, their attitude, and their relations reflect the conditions under which they were formed and the alterations they have undergone, and these data enable geologists to read the geologic history.

Land areas have been furnishing sediments and these sediments have been transported, worked over, sorted, and eventually deposited in the sea. After consolidation by cementation, compaction, or both, gravel becomes conglomerate, sand becomes sandstone, silt is converted into siltstone, clay and mud become shale. Materials in solution are precipitated to form beds of salt, gypsum, and the like; calcium carbonate is precipitated, chemically in some cases, and in some cases as organic secretions, to form limestone, or dolomite, if mixed with magnesium carbonate.

The effect of water movement is recorded in cross-bedding, rill and ripple marks. Mud cracks, rain-drop impressions, and worm borings indicate shallow water conditions. Coarse sediments indicate that the land furnishing these sediments was high and relatively near; the presence of limestone suggests that the land area was far off or that it was low-lying and possibly heavily vegetated.

Folded, warped, or faulted rocks record earth movements since their deposition. Periods in which a given area was out of water and undergoing erosion are recorded by irregular contacts between the formations deposited before and after the erosion period. Erosion periods are also recorded in the weathered surface of some formations and by the presence of fragments of an older formation in the basal portion of a younger one. Fossil remains are a part of the earth record, and a study of the changes that have taken place in the organic record preserved in the rocks permits the tracing of life development.

The geologic history of Illinois is read, in part, from rocks outcrops, and in part from well borings and shafts. Infor-

mation obtained from these sources is supplemented by knowledge derived from a study of adjacent areas. The geologic history of the events which transpired in the Streator quadrangle is also determined in a similar manner. This is permissible because the processes which were operative in the Streator area were also operative over considerable areas outside of and adjacent to the Streator quadrangle.

The record of the history in this region is incomplete. There are gaps in the record that can be filled in satisfactorily from data obtained from a study of other areas but some of the gaps cannot be filled satisfactorily even by inference. The data are fairly complete for a portion of the Paleozoic and for the latter part of the Quaternary, but this is a small fraction of geologic time. The events that took place before the Cambrian period are not known except from a study of regions to the north. The record of the events that took place during the Mesozoic and Tertiary times has been destroyed by erosion. Indeed, throughout the entire Till Plains Section the record of these areas is fragmentary.

Pre-Paleozoic Eras

Wherever pre-Cambrian rocks are exposed they show a record of periods of sedimentation separated by periods of erosion and periods in which vulcanism and diastrophism occurred. It is probable that a similar series of events took place in Illinois during these eras. Immediately preceding the Cambrian period a long period of erosion developed a peneplain in Wisconsin and adjoining areas,⁴⁹ which is now tilted in southerly direction. The present southward tilt of this surface may be due to its original slope but it is probably due to subsequent diastrophism because it is the surface on which the Cambrian rocks lie.

Paleozoic Era

The area within which the Streator quadrangle is located is known as the Eastern Interior Basin. This basin, during

⁴⁹S. Weidman and A. R. Schultz, Water Supplies of Wisconsin, Wisconsin Geological and Natural History Survey, Bulletin No. 35, 1915, Pl. I; R. S. Knappen, Geology and Mineral Resources of the Dixon Quadrangle, Illinois State Geological Survey, Bulletin No. 49, 1926, p. 34.

Paleozoic times, was a low-lying area which was frequently submerged by epi-continental seas. The alternate submergence and elevation of the region developed alternate epochs of deposition and erosion. The sediments deposited in the seas which flooded the area were derived from the highland areas to the north, from those to the southwest, and probably from Appalachia to the east. Some of the breaks in the depositional record, reflecting changes, are marked by unconformities between strata; others are marked by a change in the faunal content of the beds; others by both.

Cambrian Period

The period of erosion that was inaugurated towards the close of the pre-Cambrian apparently continued in Illinois throughout the early and middle Cambrian epochs, as no formations of those epochs are known to occur in the northern part of the state. In late Cambrian times the lowland surface was submerged and the materials composing the Croixan series were deposited. The series thickens to the south, a fact which suggests that the encroaching sea came in from the south, and the off-shore phases indicate that towards the south lay the open sea. The fact that the character of the rocks laid down during this period varies from place to place shows that the conditions of sedimentation were neither stable nor the same over large areas, although the formational divisions of the series can be recognized over wide areas.

The first deposits laid down in the advancing seas were the sands that now make up the Mt. Simon sandstone. These conditions remained constant long enough for a great thickness of sand to accumulate. Conditions then changed and finer sediments were brought in and the Eau Claire formation was deposited. A set of conditions similar to that which existed during the formation of the Mt. Simon recurred, and the Galesville sandstone was deposited; the deposition of the Galesville sands was followed by the deposition of the finer sediments of the Franconia formation. Conditions during the deposition of the latter formation were different from those during the preceding if the presence of glauconite is considered. During the deposition of most of the Trempealeau formation the waters were clear and more calcareous sediments accumulated; following this, conditions favoring the deposition of sand recurred and the Jordan sandstone was laid down during the latter part of Trempealeau time.

The Cambrian period was closed, in this area, by emergence

from the sea and the inauguration of a period of erosion during which the Madison formation, which occurs in Wisconsin, was completely eroded, granting that it had been deposited in Illinois, and the Jordan sandstone eroded until only an irregular thickness remained. It may have been during this period of emergence that the folding of the Cambrian rocks recorded in the Dresbach formation took place. In the Streator quadrangle the erosion which occurred at this time removed the Trempealeau and part of the Franconia as well.

Ordovician Period

Early Ordovician time was marked by an invasion of the sea in which a great thickness of materials was deposited. That this sea was clearer than the Cambrian waters is indicated by the fact that the lower Ordovician rocks are chiefly chemical or organic precipitates. Conditions, however, must have fluctuated sufficiently to allow deposition of sandstone at times, because the deposition of the Oneota dolomite was followed by the deposition of the New Richmond formation, which is sandstone.

The water again cleared and towards the end of the Prairie du Chien times the Shakopee dolomite was deposited. The ripple marks, oolites, mudcracks, and breccia have been interpreted as deposition in shallow water and exposure on tidal flats.⁵⁰ In the exposure between Utica and La Salle there is evidence of warping in the Shakopee that is not reflected in the overlying St. Peter sandstone. Due to diastrophism or unequal settling and compaction apparently slight deformation of the Shakopee took place some time after its deposition and before the deposition of the St. Peter. This warping probably took place during the emergence that closed the early Ordovician epoch.

During the period of emergence that followed the withdrawal of the early Ordovician sea, erosion removed a great deal of the Shakopee dolomite with the development of a relief of several hundred feet,⁵¹ and locally in northern Illinois the entire Prairie du Chien series was eroded.⁵² In places the Shakopee was

⁵⁰Ibid., pp. 82-85.

⁵¹D. J. Fisher, Geology and Mineral Resources of the Joliet Quadrangle, Illinois Geological Survey, Bulletin No. 51, 1925, p. 20, Pl. III.

⁵²F. T. Thwaites, Stratigraphy and Geologic Structure of Northern Illinois, Illinois Geological Survey, Report of Investigations, No. 13, 1927, pp. 22-23.

deeply weathered developing a regolith, or "mantle rock," composed of a residual clay, with nodules of flint, two to three feet thick.⁵³

Middle Ordovician epoch.--After the period of emergence and erosion which closed the early Ordovician epoch the sea again advanced upon the area. Eventually the region was submerged and in this sea were deposited the well sorted, well rounded, frosted, pitted grains of which the St. Peter sandstone is composed. The frosted, pitted characteristics of these grains have been interpreted as wind action, probably in a desert bordering the sea.⁵⁴ However, the prevalence of horizontal bedding and the presence, locally, of marine fossils indicate that the sandstone is a marine deposit. Following the deposition of the St. Peter there was a slight emergence which seems to have been local. In the Streator quadrangle the Platteville-Galena lies unconformably upon the sandstone while elsewhere there seems to be a transition from the St. Peter into the overlying beds.⁵⁵

Following the emergence there was a transgression of the sea in Platteville times. The waters were probably warm and apparently free from clastic materials. There was an abundance of life present and the shells, with some calcareous ooze and a little mud, formed the dominant sediments during the Platteville and Galena stages. The Galena is remarkably free from shale and sand, indicating a long period of fairly constant conditions of sedimentation. This epoch was followed by a widespread emergence with the accompanying weathering and erosion. Some time following the deposition of the Platteville-Galena formations and before the deposition of the Pennsylvanian horizons a period of folding reflected in the St. Peter sandstone and all other pre-Pennsylvanian formations of the region occurred along the axis of the La Salle anticline.

Post-Galena--Pre-Pennsylvanian interval.--The absence of any sediments belonging to the periods between the mid-Ordovician

⁵³G. H. Cady, Geology and Mineral Resources of the Hennepin and La Salle Quadrangles, Illinois Geological Survey, Bulletin No. 37, 1919, p. 92.

⁵⁴C. L. Dake, The Problem of the St. Peter Sandstone, University of Missouri School of Mines and Metallurgy, Bulletin Technical Series, Vol. VI (1921), No. 1.

⁵⁵H. R. Wanless, Geology and Mineral Resources of the Alexis Quadrangle, Illinois Geological Survey, Bulletin No. 57, 1929, p. 118.

and the Pennsylvanian leaves the history of this interval in doubt, although sediments of these periods are present in the adjoining areas. If such formations were deposited within the area they were removed by erosion before the Pennsylvanian sediments were laid down.

Pennsylvanian Period

Pottsville epoch.--The erosion period recorded by the unconformity between the Platteville-Galena dolomites and the Pennsylvanian formations continued until the latter part of the Pottsville epoch. The Liverpool cyclothem was inaugurated by the deposition upon the eroded surface of the Ordovician rocks of a fine-grained sand which filled some of the depression of the old topography. After the deposition of the sand the area became the site of brackishwater or fresh water swamps in which muds accumulated. These swamp conditions marked the close of the Pottsville epoch.

Carbondale epoch.--The Carbondale epoch began with widespread marsh conditions which were continuous over hundreds of square miles in northern, western, and central Illinois, including the area covered by the Streator quadrangle. The growth of vegetation and the accumulation of vegetable material in this widespread swamp was terminated by an invasion of the sea. The swamp and marsh debris had become peat as it accumulated. It was later metamorphosed into the Colchester (No. 2) coal. Weathering or alteration processes prior to, contemporaneous with, or after the plant growth, transformed the material directly underlying the coal into an underclay. In the muddy sea waters that then invaded the area mud-loving marine forms, gastropods, pelecypods, ostracods, and worms were present. The origin of the black, laminated shale which occurs above the coal has not been satisfactorily explained. It does not seem to have been derived from organic material obtained from erosion of the underlying coal because the black shale is as widespread and as persistent as the coal itself. Nor does the shale come in contact with the coal except in small areas, and even where it does the coal does not seem to have been thinned by erosion. It may be an ordinary mud deposited in stagnant or quiet water in which floating carbonaceous material became waterlogged and sank, decaying under the influence of bacterial action instead of merely being buried in the mud. The sand grains and plant fragments found in some of

the small calcareous concretions in the shale were probably dropped from floating masses. The numerous concretions present in the shale were apparently formed before the mud had become consolidated, because the thin laminations bend around the concretions. After the deposition of the black mud conditions again changed and a mud, similar to that which was deposited before the black shale, was again deposited, and marine forms of life were present in large numbers. Occasionally calcareous muds accumulated and these now form the septarian limestone found above the No. 2 coal; when the water was clear enough for the calcareous muds to accumulate, corals and crinoids were present, but when the waters were muddy the dominant life consisted of the forms adapted to silty waters. This phase of deposition was terminated and the Liverpool cyclothem closed by a withdrawal of the sea from the region.

Following the emergence of the area from the sea, streams again began eroding the materials deposited in the inundation and cutting down through the silts, muds, and calcareous deposits. After this period of erosion the Sumnum cyclothem began with the deposition of sand which filled the stream channels and covered the old uplands. This sand formed the Pleasantview sandstone and is the base of the Sumnum cyclothem. After the deposition of the sand, parts of the area became swampy and locally peat bogs were formed which eventually developed what is now known as the No. 4 coal. The horizon of the No. 4 coal level was altered prior to, coincident with, or after the formation of the coal to form a thick underclay where the coal is present and a non-calcareous clay where the coal is absent. These conditions lasted until an encroaching sea invaded the area, and worked over the clay, muds, and carbonaceous material until a widespread deposit of carbonaceous shale was developed. Marine conditions continued after the waters cleared and the area became the site of deposition for calcareous materials. With the clearing of the water many forms of marine life invaded the area. The waters may have been shallow enough to form tidal flats because the limestone which formed under these conditions presents a brecciated appearance and the relationship of it to the non-brecciated materials above and below suggests that drying produced a desiccation breccia or the fracturing occurred due to wave action soon after the calcareous mud had partially consolidated. Finally the waters became muddy

again, the calcareous material was no longer deposited, and the sea was no longer suitable for the existence of marine life.

After the last muds were deposited the sea again withdrew closing the Sumnum cyclothem and the area became a site of erosion. Streams cut their channels across the region, locally stripping the shales from above the limestone.

The St. David cyclothem was inaugurated by the deposition of an interesting conglomerate on the eroded surface. Just what the conditions were that existed when the Waupecan conglomerate was laid down and what the source of material was has not been answered satisfactorily. The characteristic angularity of the fragments indicates that the material had not been transported great distances. The rounding of some of the fragments suggests stream action. The presence of some cobblestones indicates that occasionally the stream had considerable velocity. But the widespread distribution of this thin layer indicates that the material does not represent channel deposition, but, rather, flood plain conditions. These conditions apparently lasted for only a short time if the thickness of the deposit is indicative. Following the deposition of the Waupecan conglomerate widespread swamp and marsh conditions existed, during which muds were laid down. These muds have since altered to a non-bedded calcareous clay. Overlying the clay is a carbonaceous layer containing locally thin streaks of coal. This is the horizon of the No. 5 coal, which in the Streator quadrangle did not develop into a workable bed. After the development of the swamps an invasion of the sea killed what vegetation had been present. In the muddy waters that invaded the area were numerous forms of marine life whose hard parts mingled with the muds that were deposited. Then conditions changed again and large amounts of carbonaceous matter accumulated with the mud to form a fissile shale. The carbonaceous material gradually settled out with a return to the conditions suitable for the formation of shale. With the deposition of the material overlying the fissile shale numerous gastropods, adapted to muddy waters, invaded the area. Still later, numerous spores and spore cases drifted into the area, and there developed a deposit of these materials which eventually became cannel coal. The source from which this plant material was derived is at present undetermined. A return of the conditions which existed before the deposition of the coal permitted the accumulation of more mud. The sea then withdrew and the St. David cyclothem closed

with an emergence of this region from the sea.

A period of erosion was inaugurated during which streams developed a fairly rough topography. In some places the Canton shale, the last material to be deposited, was completely removed, and the cannel coal was cut out at numerous places. The period of active erosion was followed by another accumulation of sand which forms the base of the Brereton cyclothem, and which filled the channels and spread out over the top of the divides. As erosion continued elsewhere, coal was uncovered on the old land mass and a large quantity of coaly material was washed into the region, developing, locally, thick beds of drift coal, which were separated from one another by thick deposits of sand. The land mass which furnished the sand and coal also contributed numerous plant remains which were washed into the area and deposited. It is possible that the drift coals have developed through the coalification of plant materials that had been washed into the area with the enclosing sands. The gradient of the streams decreased and only silts and muds were brought into this region. Following the deposition of the muds the gradient of the streams increased and sand again was brought in and deposited. After the deposition of the last sand finer materials were again deposited, and were altered subsequently to an underclay. The conditions that prevailed towards the end of the last period of deposition were probably similar to the fresh water or brackish water swamps and marshes that exist today, and locally large amounts of accumulated plant material became peat and eventually formed the lower bench of the No. 6 coal. For a short time the swamp condition was interrupted and clay was deposited. Following this, the swamp conditions again prevailed and vegetation, which later formed the upper bench of the No. 6 coal, accumulated.

McLeansboro epoch.--The opening of the McLeansboro epoch was marked by a widespread submergence of the region. The waters of this sea were silty and the sediments formed a thick layer of siltstone before the waters cleared. The clearing water permitted the accumulation of calcareous muds and numerous shells and tests of marine organisms adapted to a clear water environment. The clear water soon gave way to muddy waters and a clay-like material, in which were trapped numerous shells, was deposited over most of the region. The seas withdrew, closing the Brereton cyclothem, and a period of erosion was inaugurated.

The erosion continued, with streams channeling the old deposits, locally removing the material above the Brereton limestone and in places cutting the limestone. Conditions then changed and the Sparland cyclothem began with streams bringing in sediments, filling the old channels and spreading out sand deposits between channels. Stream gradients were reduced, either by erosion or subsidence of the area furnishing the sediments, and finer materials were deposited which have subsequently become an underclay. Following the deposition of the finer sediments there was a recurrence of the fresh or brackish water swamps, with the accompanying vegetation. In these swamps accumulated the vegetable material which now forms the No. 7 coal. The swamp environment was terminated by an invasion of the sea in which a great deal of mud was present. The muds settled, forming a thick layer on the swamp deposits. Following the deposition of the muds the Sparland cyclothem closed as the area emerged and another period of erosion began.

This erosion interval was terminated by a recurrence of the conditions which permitted the deposition of sand in the stream channels inaugurating the Gimlet cyclothem. As before, conditions changed to permit the bringing in and deposition of finer materials, so that the upper part of the sands forming the Gimlet sandstone in this area is silty to shaly.

If any Pennsylvanian strata younger than the Gimlet sandstone were deposited in the Streator quadrangle they were completely removed by the erosion that occurred between the Pennsylvanian period and the Pleistocene.

Close of the Paleozoic Era

The last period of the Paleozoic, known as the Permian, is not represented in northern Illinois except near Danville. Deposition of Permian deposits may have taken place in the Streator quadrangle, but if so they were removed by erosion before the beginning of the Pleistocene.

Evidence obtained from wells in the southeastern part of the State indicates that the younger Pennsylvanian rocks are practically horizontal and the older Pennsylvanian strata have been folded.⁵⁶ As the highest Pennsylvanian rocks in the Streator area

⁵⁶Cady, La Salle Anticline, Illinois Geological Survey, Bulletin No. 36, 1920, p. 176.

are, probably, well below the outcropping strata in the southeastern part of the State, it is probable that the development of the La Salle anticline had been completed entirely within Pennsylvanian times.

However, it is probable that the diastrophism during and at the close of the Permian which resulted in the folding of the Appalachian Mountains on the east and the uplift of the Ouachita and Ozark Mountains on the west, bringing to a close the Paleozoic in North America, resulted in an uplift of the area in which the Streator quadrangle is located.

Post-Paleozoic--Pre-Pleistocene interval.--This interval includes all of the Mesozoic era and that part of the Cenozoic preceding the Pleistocene period. After the withdrawal of the sea in late Pennsylvanian times the upper Mississippi valley seems to have been a land area subject to erosion and intermittent uplift with the development of at least two peneplains which have been recognized. In the "Driftless Area" of northern Illinois, southwestern Wisconsin, parts of Iowa and Minnesota, a high level peneplain was developed. It is called the Dodgeville peneplain⁵⁷ and has been interpreted as representing erosion to the Cretaceous period. This peneplain was uplifted and dissected with the development of the Lancaster peneplain⁵⁸ at a lower level. The erosion cycle in which this peneplain was developed reduced the area so that by Pliocene times the region was one of low relief with remnants of the Dodgeville peneplain forming the upland areas. At the close of the Pliocene period there was an elevation of the Interior Province with respect to sea level. The master stream of the region was the present Mississippi River, but at this time it flowed eastward from the present vicinity of Clinton to about the position of Hennepin on the Illinois River. From there it flowed to the south in a valley that approximated the present position of the Illinois River valley. The pre-glacial streams of the Streator quadrangle probably drained westward towards the master stream, and following the uplift which closed the Pliocene these streams cut several deep valleys into the Pliocene peneplain (see

⁵⁷A. C. Trowbridge, The Erosional History of the Driftless Area, Part II, University of Iowa Studies in Natural History, IX (1922), 55-127.

⁵⁸U. S. Grant and E. F. Burchard, Lancaster-Mineral Point Folio, United States Geological Survey Atlas, No. 145, 1907, p. 10.

Fig. 4), the most important of which is a large valley in the northern part of the quadrangle, in T. 32 N., R. 2, 3, and 4 E., indicated by wells and exposures along the Vermilion River in the northwest part of the quadrangle. As shown on the surficial geology map in T. 32 N., R. 2 E., the southernmost outcrops in sections 22, 23, and 24, along the north side of the preglacial valley are aligned in an east-west direction. The northernmost outcrops in T. 32 N., R. 2 E., sections 35 and 36, and T. 32 N., R. 3 E., sections 31 and 32, are also aligned in an east-west direction. Within these outcrops there is a zone about two miles wide in which the Vermilion River and its tributaries have cut their valleys in till to a depth of one hundred feet.

To the east, in T. 32 N., R. 3 and 4 E., wells have been drilled one and two hundred feet deep; the well at Grand Ridge is reported to have been drilled 450 feet deep, without encountering bed rock.

Pleistocene Period

World-wide climatic changes occurring at the close of the Pliocene permitted snow and ice to accumulate over large areas in the northern hemisphere. These materials accumulated to form continental ice caps in relatively high latitudes from which they spread out in all directions. During this period continental glaciers invaded the Mississippi valley states four times, spreading from three principal centers: (1) the Labradorean center, in the highlands of eastern Quebec and Labrador; (2) the Keewatin center, lying in the southwest and west of Hudson Bay; (3) the Cordilleran center, in the Canadian Rocky Mountains. Each of the invasions was followed by a period of milder climate during which the ice sheet melted away. These invasions named in order were: Nebraskan, Kansan, Illinoian, and Wisconsin.

Pre-Wisconsin epoch.--Wisconsin drift covers the quadrangle and nothing definite is known concerning the earlier invasions. However, a short distance to the south of the area there is an exposure of till older than the Wisconsin; but the relations at this exposure do not permit determination of the age as Illinoian or pre-Illinoian. The present distribution of deposits of Illinoian age suggests that Illinoian ice extended over the quadrangle.

Wisconsin epoch.--The interglacial period was terminated by a recurrence of glacial conditions which permitted the Wisconsin

ice to form and invade this region. The ice that invaded Illinois advanced from the northeast, spreading out from the Labradorian center of accumulation, the front of the ice moving forward as the rate of ice movement exceeded the rate of melting. As the ice front advanced into lower latitudes the rate of melting increased. Finally, when melting equalled the rate of ice advance the front remained stationary, and whenever the rate of melting exceeded that of the ice movement the front retreated. Numerous oscillations occurred during the retreating stage of the ice and probably numerous haltings and retreats occurred during the general advance of the ice until it reached its maximum extent during the Shelbyville stage, when it built a conspicuous terminal moraine several miles west of the Streator quadrangle. The Wisconsin ice did not advance to its maximum position and then retreat continuously, but during the recession of the ice there were numerous minor re-advances referred to as stages. It is impossible to determine how far the ice had retreated at the end of each recessional stage but the distance was far enough for the re-advancing ice to override the till sheets deposited during the earlier stages, and for the marginal outline to be distinctly different from the preceding front. As in the case of the maximum extent of the ice the position of greatest extent during each of the re-advances is marked by an end moraine. These moraines, of Wisconsin age, have been named ordinarily from a town that is located on or near the moraine. In order of age from oldest to youngest, the moraines younger than the Shelbyville in Illinois are the Cerro Gordo, Champaign, Bloomington, Normal, Cropsey (developing a complex terminal morainic system of three moraines), Farm Ridge, Chatsworth, Marseilles, Minooka, Manhattan-Rockdale, Valparaiso, and the Lake Border.

It is probable that the Wisconsin ice during all the stages represented by the above-named moraines, preceding and including the Chatsworth, retreated and then re-advanced across all or--as in the case of the Farm Ridge and Chatsworth--a small part of the Streator quadrangle.

Like all glaciers, the Wisconsin ice picked up some of the material from the floor over which it moved, incorporated this debris in itself, and deposited it when it melted. Whenever the front of the ice was stationary the debris carried by the ice was deposited in a pronounced ridge of till, or unassorted drift,



Fig. 1.--Map showing moraines in northeastern Illinois

called an end moraine. Under the ice and as the ice receded, a relatively thin sheet of till was deposited, forming a ground moraine. Water from the melting ice, as a rule, flowed directly away from the glacier and deposited an outwash plain or apron. Where the escaping water was confined to valleys the outwash material formed valley fills or valley trains. In some instances the streams discharging at the front of the ice built mounds of rudely stratified gravels and sands, called kames. Here and there streams flowing beneath, or in the ice, deposited sorted materials along their course which, when the glacier melted, were left as ridges of gravel, called eskers.

There are present in the Streator quadrangle drift sheets of the Shelbyville, Bloomington, Cropsey, and Farm Ridge; also parts of the terminal moraines of the third Cropsey, Farm Ridge, and Chatsworth. Whatever drift may have been deposited by intervening stages has been incorporated in the drifts of the stages mentioned above.

Shelbyville stage

As the ice of the Shelbyville stage advanced into the area it was probably preceded by outwash from the advancing glacier. As it passed over the Streator quadrangle it removed the outwash material and scoured the surface of the floor down to bed rock. The ice advanced as far as Shelbyville to the southwest and as far as Peoria to the west. With an amelioration of the climate the ice melted back until it uncovered the Streator quadrangle. How far to the east the front of the ice stood during the interval between this retreat and the advance that took place during the Bloomington stage is not known. That it uncovered the area under consideration is indicated by the contact between the Shelbyville till and the overlying Bloomington drift. The surface of the Shelbyville till sheet must have been covered with outwash material deposited during the retreat of the ice.

Bloomington stage

A recurrence of a cold climate permitted the ice to re-advance over the area. During this advance the Bloomington ice removed any outwash material that was present on top of the underlying till and in many places removed the Shelbyville till as well. Locally, the ice rode over outwash materials and perhaps over lacustrine deposits that had been laid down during the Shelbyville-Bloomington non-glacial interval. This advance carried the ice

as far west as Peoria but not as far to the southwest as the previous advance. To the south it reached to Bloomington and almost to Danville. At the farthest advance the front of the ice was stationary long enough to allow the building of a strong marginal moraine. Again the climate changed and the rate of melting exceeded the rate of ice advance with the result that a period of deglaciation occurred. Behind the Bloomington terminal moraine and in front of the receding front of the ice a lake was formed with the surface at approximately six hundred feet above sea level. During the retreat of the ice a considerable amount of material was deposited in this glacial lake. The ice receded to a position east of the quadrangle perhaps as far as Joliet,⁵⁹ leaving the area under water.

Cropsey stage

With a return of glacial conditions the ice advanced into the lake, depositing outwash material upon the lacustrine deposits, and as the ice rode over these it removed some of the materials so that the Cropsey till locally is separated from the Bloomington by a few inches of sand or silt. The Cropsey ice moved westward across the Streator quadrangle and the front of the ice halted a few miles west of the area, building up a complex terminal morainic system with the inner edge of the inner ridge (sometimes called the "Third Cropsey") lying several miles inside the Streator quadrangle. When the ice retreated from this position water flooded into the area and filled the basin formed by the retreating ice front and the moraine again to the six hundred foot level. How far to the east this retreat continued has not been determined. The next advance of the ice inaugurated the Farm Ridge stage.

Farm Ridge stage

A lowering temperature resulted in an ice advance, the major portion of which was to the north of the Streator quadrangle. The southern edge of the Farm Ridge lobe lay across the northern part of the quadrangle. The melting ice drained south into the six hundred foot lake, building deltas at that level with the debris obtained from the glacier. The ice did not reach as far west as the third Cropsey; the waters drained from the area to the northwest through the gap formed between the two terminal moraines. With a more congenial climate, the Farm Ridge ice retreated

⁵⁹M. M. Leighton, Unpublished notes.



Fig. 2.--Delta at gravel pit, NW1/4 SE1/4 section 5, T. 31 N., R. 3 E., showing delta structure developed by Farm Ridge outwash at an elevation between 600 and 610 feet above sea level.

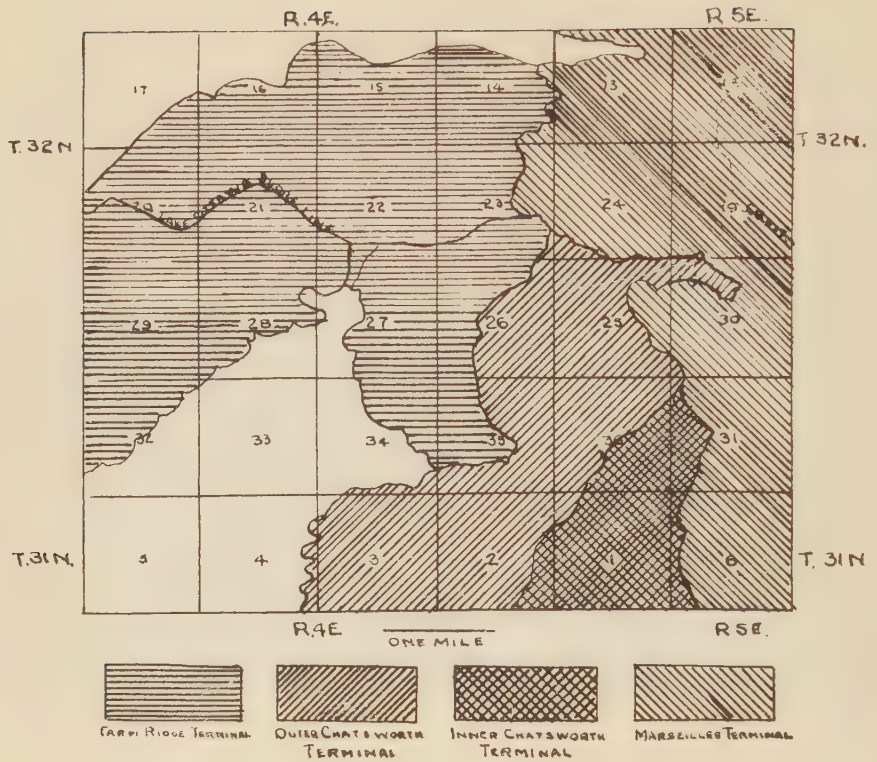


Fig. 3.--Map showing relationship of end moraines just east of the Streator Quadrangle.

with the formation of another marginal lake to the north.⁶⁰

Chatsworth stage

Later the ice advanced from the east, again moving onto the quadrangle almost as far as the site of the city of Streator. Here the rate of melting was fast enough to maintain a relatively stationary ice front. During the halt in this position the Chatsworth ice developed a terminal moraine, retreated a short distance, and then built an inner ridge which in places rides up on the first moraine developed. Northeast of the quadrangle the Chatsworth terminal overrides the Farm Ridge terminal, demonstrating that it is somewhat younger than the Farm Ridge. Outwash from the Chatsworth formed an apron along the front of the ice and locally the water was concentrated along valleys to form small valley trains of gravel. That the six hundred foot lake had not been drained by this time is evidenced by the fact that the outwash from the Chatsworth formed deltas at that elevation. Again a rise in temperature caused the Chatsworth ice to retreat to the east. How long after this the six hundred foot lake maintained its position is not known. Certainly it persisted until the Bloomington moraine had been trenched sufficiently to lower the outlet.

Interval between the Chatsworth stage and the Kankakee Torrent stage

After the retreat of the Chatsworth ice there were several re-advances, none of which reached as far west as the Streator quadrangle. Undoubtedly water draining from these younger ice sheets drained into the Streator area; there was, however, no deposition nor appreciable erosion during these stages.

Kankakee Torrent stage

During the closing stages of the Pleistocene period in northeastern Illinois a large volume of water filled the Kankakee and Iroquois basins. Most of the water drained out through the Kankakee River, forming what has been called the Kankakee Torrent,⁶¹ but large quantities of the waters spilled out through the Iroquois basin into the Vermilion River. The torrential wa-

⁶⁰Cady, The Geology and Mineral Resources of the Hennepin and La Salle Quadrangles, Illinois Geological Survey, Bulletin No. 37, 1919, p. 100.

⁶¹G. E. Ekblaw and L. F. Athy, "Kankakee Torrent in Northeastern Illinois," Geological Society of America Bulletin, XXXVI (1925), 417-28.

ters flowed into the Streator area so rapidly that the narrow outlet formed between the Farm Ridge and the Cropsey moraines was not capable of draining the area. The waters ponded at this outlet and rose to a 650-foot level. At the same time the waters of the torrent, passing down the Illinois River, rose in the vicinity of Ottawa to a 640-foot level. The 650-foot lake was separated from the 640-foot lake, on the Streator quadrangle, by the Farm Ridge moraine. The 640-foot lake had an outlet down the Illinois River; the 650-foot lake had two outlets on the Streator quadrangle, one to the northwest through the Vermilion River, and the other across the Farm Ridge moraine in the northeastern part of the area.

Erosion was not a dominant feature during this stage although some current scouring is noticeable along the fronts of the Chatsworth and Farm Ridge moraines. Deposition, however, was active. The central part of the lake is now practically a flat plain covered with silts several feet thick, except where some of the original drift deposits were present as islands. The littoral portions are not well developed, except in the few cases where the scouring is marked; they consist of the original drift surfaces modified by the lacustrine conditions. At the northeast outlet, where the water spilled across the Farm Ridge moraine, a well-developed channel was produced, and at the northwest outlet a well-developed 650-foot terrace was formed with pronounced gravel bars near the upstream side of the outlet.

These conditions existed until the ice, which was furnishing the water, had melted back far enough to allow free drainage into the Wabash River and the incipient Lake Chicago.

When the supply of water became less the water level in the Streator basin lowered and the water flowing off the west slope of the lake flat scoured the unconsolidated silts, producing rather large valleys which are now occupied by relatively insignificant streams. As the surface of the water continued to fall terraces were left at different levels.

Five terraces have been noted below the 650-foot level. The 600-foot terrace, where the deposits are all sand and gravel and of which much shows deltaic structure, is probably due to the presence of Lake Illinois. The others, all of which are lower, and are composed of silt and fine alluvium, seem to be related to the closing stage of the Kankakee Torrent, or to the lowering of

the Illinois River during the closing stage of its functioning as the outlet of Lake Chicago.

Drainage changes

The pre-Pleistocene drainage differed somewhat from that which exists today. Drainage was apparently to the west and southwest. A large valley existed in the northwest portion of the area and probably drained westward to the pre-glacial Mississippi. Drill records indicate that there was another large valley in the central part of the quadrangle trending northeast-southwest. As the master stream of the region lay to the west this valley probably drained southwest. To the east, near the line between La Salle and Grundy counties, there was another large valley draining south. It is likely that some of the drainage in the eastern part of the Streator quadrangle entered this valley.

The whole pre-glacial stream pattern was destroyed by the advance of the ice. With the formation of the third Cropsey and the Farm Ridge moraines, drainage from the area was diverted to the northwest, the present position of the Vermilion River valley probably having been determined by the relatively low gap between these two moraines. The position of the tributaries on the east side of the Vermilion in this area was determined by the outwash from the Chatsworth ice. Those west of the river seem to have been located by the scouring action of the receding waters of the Kankakee Torrent.

Recent epoch.--Since the Vermilion ceased to be an outlet for the Kankakee Torrent and the water level dropped to about its present position, there has been little change in the topography, except perhaps in those areas immediately bordering the streams and at the lower portions of the streams tributary to the Vermilion River. Numerous small lakes and swamps of the upland have since been drained or filled, but there has been no particular topographic change developed, and as far as is known there has been no change in altitude.

Weathering of the surface materials developed soils, and vegetation encroached upon the area. On the level stream divides prairie plants took possession and on the slopes and bottom lands forests grew.

Since man came into the region, cultivated the soils, and cut the forests, there has been local concentration of the runoff with the development of gullies on the sloping surfaces. Arti-

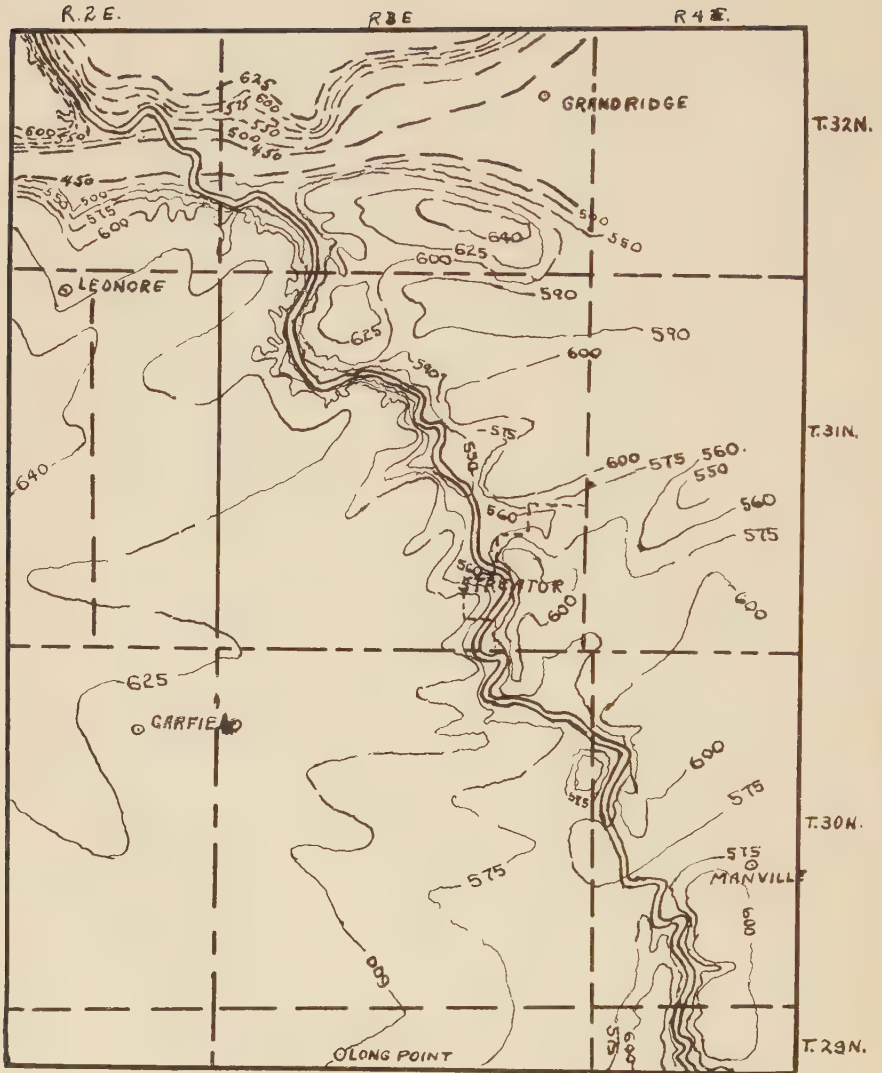


Fig. 4.--Bedrock topography of the Streator Quadrangle

ficial drainage (a large portion of the southwestern part of the quadrangle has been tiled) enables the water of heavy rains to reach the main streams quickly and increase the frequency of the flooding of their plains. Locally coal mining has caused subsidence of the surface and has created a serious problem for land owners who are interested in agriculture.

CHAPTER VI

ECONOMIC GEOLOGY

The mineral resources of the Streator quadrangle consist of coal, shale, siltstone, and sand and gravel. Oil and gas have been prospected for with no success. Other natural resources are surface and underground waters and soils.

Coal

The quadrangle is part of the District I, or Longwall District, of the Illinois Coal Field.⁶² The district consists of Putman County and parts of Bureau, Grundy, Kankakee, La Salle, Livingston, Marshall, and Will counties. The district has been subdivided into several fields, of which those important in this quadrangle are the Kangley-Heenanville Field and the Streator Field, both of which are in the central portion of the area under consideration.

At one time these fields were the site of much activity. There were several shipping mines located at Streator and at Kangley and Heenanville. At the time of this study there were no shipping mines; Kangley was practically a deserted village and Heenanville a memory. Streator has remained an important industrial and trading center due to resources other than coal.

The State and Federal Geological Surveys have in general preferred place names for coals rather than numerals. Therefore, Dr. Cady has introduced the terms "Streator" and "Danville" for coal No. 7 (in this report, however, the Streator coal is correlated with coal No. 6), "Herrin" or "Bellevue" coal for coal No. 6, "Springfield" or "Harrisburg" for the No. 5 coal, and "Murphyboro" or "La Salle" for the No. 2 coal.⁶³ Since, however, the numeral nomenclature is rather firmly established and because in this report correlations are made with coals named from towns

⁶²Cady, Coal Resources of District I (Longwall), Illinois State Geological Survey Co-operative Mining Series, Bulletin No. 10, 1915.

⁶³Ibid., p. 58.

not within the limits of the Longwall District, and since there is a tendency to number the coals according to the position of the cyclothem containing the coal, the procedure in this report will be to use a place name as well as a number wherever it is possible.

The La Salle (No. 2) coal and the Streator (No. 6) coal are the important coals in the quadrangle. There are several other coals present but none of importance. The extent of these two is fairly well established through drilling and mining operations.

Carbondale Coal

La Salle (No. 2) coal.--The most important coal, as far as extent is concerned, is the La Salle coal, which has been correlated with the Colchester No. 2 coal of western Illinois. The coal varies in thickness from about one foot to three feet. At the outcrop in the northwestern part of the Streator quadrangle it is twenty inches thick and in the shaft record of the Chicago, Wilmington, and Vermilion Coal Company Mine No. 2, it is logged as forty-eight inches thick. With the exception of about one square mile in the northwestern part of the area, the coal underlies the entire quadrangle.

Due to the structure of the region the coal, on the east flank of the La Salle Anticline, is at Kangley about 180 feet below the surface; at Streator about 220 feet below the ground; and at Cornell, a few miles southeast of the quadrangle, the coal is nearly 280 feet below the surface of the ground. There is about 220 square miles of coal averaging thirty inches thick. As Illinois coals have an average specific gravity of about 1.3 there are approximately 1,770 tons of coal to the acre-foot. This indicates a reserve of about 623,000,000 tons of available coal. The depth and thinness of the coal make it inadvisable to work under present market conditions.

This coal is of long grain that splits most readily parallel to the bedding planes. It is rather hard and brittle and locally the upper part of the coal is harder than the lower. The bedded impurities consist of thin layers, lenses or nodules, of mother coal, clay and marcasite (locally pyrite) and occasionally bone coal. These, however, make a small percentage of the mass of the coal bed.

The coal has an ash content of 8.45 per cent, which is less than the average for the State, and a sulphur content of 3.45 per cent, which is slightly above the average for the State.

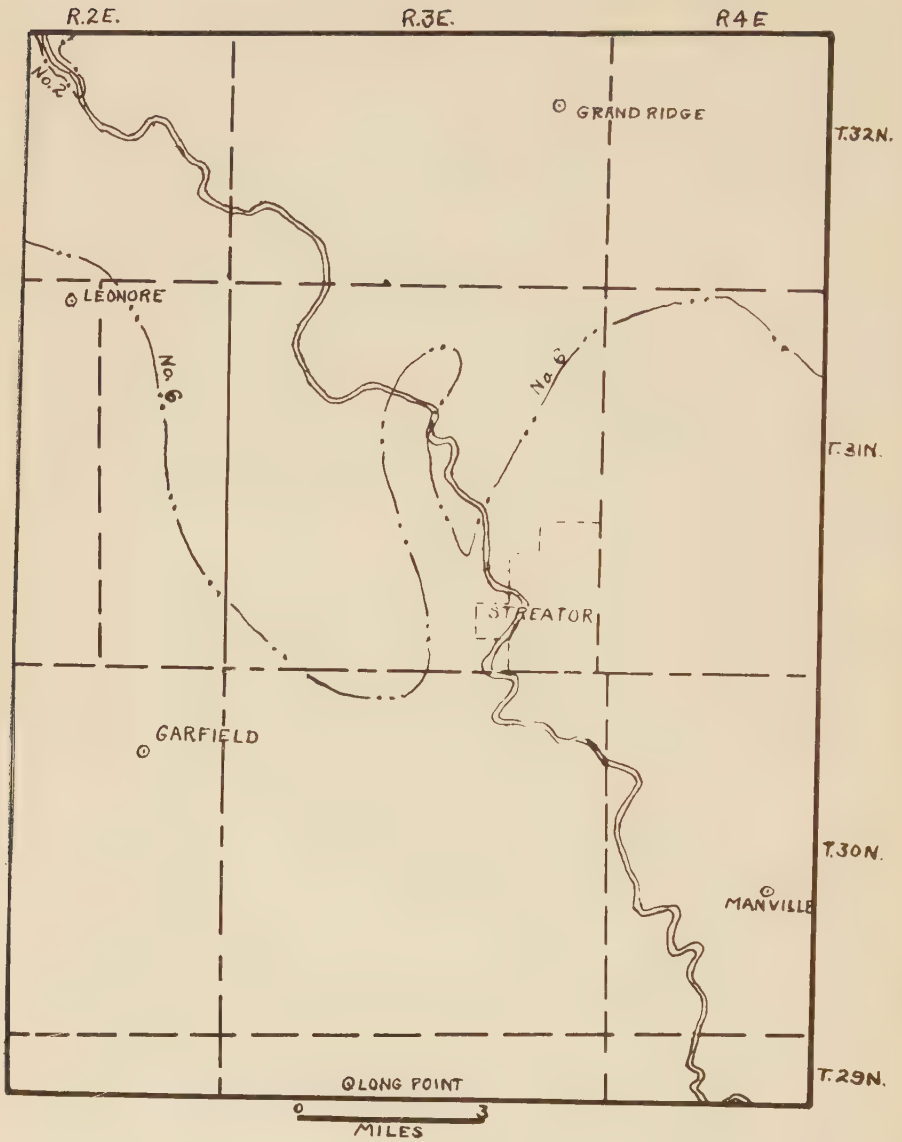


Fig. 5.--Approximate boundaries of the No. 2 and No. 6 coals.

The water content is considerably higher than in any other coal in the State, averaging about 16.18 per cent; the heating value averages about 10,980 B. T. U. Detailed proximate analysis of this coal has been published by the Illinois State Geological Survey.⁶⁴

The roof consists, over most of the area, of a gray shale. Locally black fissile shale, about three feet thick and containing ironstone concretions, rests directly on the coal.

The floor of the coal is an underclay several feet thick. The mine of the Streator Clay Manufacturing Company reports this clay fourteen feet thick.⁶⁵ Along the crest of the anticline where water has access to the clay the floor in the mine is reported to heave rather badly.

Coals between the La Salle (No. 2) and the Streator (No. 6) coals.--A thin, stray coal, in the Liverpool cyclothem, crops out in the cut bank of the Vermilion River just below the Lowell Bridge, about thirty feet above the No. 2 coal (see Geologic Section No. 1). The same coal appears only as a streak in the western part of the area. The record of the shaft of the Chicago, Wilmington, and Vermilion Coal Company's mine No. 1 at Heenanville does not log the coal at all, while the record of the shaft for the No. 2 mine of the same company at Streator logs a twenty-eight inch coal at this horizon. The extent and thickness of this coal is not known but it is unlikely that it has an economic importance.

Partial Log of Shaft No. 1, Chicago, Wilmington, and Vermilion Coal Company, Heenanville, La Salle County, Section 10, T.31 N., R. 3 E. (Geologic interpretation by the author)

Description of the Strata	Thickness		Depth	
	Feet	Inches	Feet	Inches
Recent				
39. Filled ground	4		4	
38. Black soil	1	6	5	6
Pleistocene				
37. Yellow clay	9	6	15	
36. Silt and sand	3	6	18	6
35. Hard pan	12	6	31	
34. Blue clay	10		41	
33. Hard pan	14		55	
Pennsylvanian				
Sparland Cyclothem				
32. Soapstone	2		57	
31. Hard rock sand	2		59	

⁶⁴G. W. Hawley, Analysis of Illinois Coals, Illinois State Geological Survey Mining Investigations, Bulletin No. 27, 1923.

⁶⁵Cady, Coal Resources of District No. 1 (Longwall), p. 72.

	Thickness		Depth	
	Feet	Inches	Feet	Inches
Brereton Cyclothem				
30. "Soapstone" boulders	4	6	63	6
29. Hard flint rock	2	6	66	
28. Dark shale	1		67	
27. Black shale	10		77	
26. Gray shale	15		92	
25. Coal No. 6 and probably No. 6X	9		101	
24. Black slate	2		103	
23. Hard sand rock (Vermilion- ville)	25		128	
St. David Cyclothem				
22. Coal slate (probably cannel)	1		129	
21. Dark shale	13		142	
20. Black slate	2	6	144	6
Sumnum Cyclothem				
19. Flint rock	5	6	150	
18. Black slate	2	6	152	6
17. Poor coal No. 4	1	6	154	
16. Fireclay and boulders	4		158	
15. Gray shale	4		162	
14. Hard sand rock (Pleasantview)	1		163	
Liverpool Cyclothem				
13. Gray shale	2		165	
12. Black slate		2	165	2
11. Gray shale	3		168	2
10. Hard sand rock	1	10	170	
9. Gray shale	3		173	
8. Dark sand rock	3		176	
7. Black slate	3	6	179	6
6. Clay shale (soapstone)	27	7	207	1
5. Coal No. 2	2	10	209	11
4. Fireclay	8		217	11
3. Sandrock	9		226	11

The No. 4 coal of the Sumnum cyclothem is exposed in the ditch on the north side of the road just to the east of the bridge at Sandy Ford. At this station the coal is three to four inches thick (see Geologic Section No. 6). This coal thickens to the southeast and in the vicinity of Klein Bridge it has been penetrated by a shaft located on the river flood plain just south and east of the bridge. It is exposed in this shaft and is approximately twenty-two inches thick. The coal is forty feet below the surface of the ground at this location and has been developed. The mine shaft at Heenanville also penetrates this horizon and it is logged in the record of this shaft as 154 feet below the surface and twenty inches thick. The shaft of the No. 2 mine at Streator indicated a thickness of thirty inches for this horizon at a depth of eighty feet. This coal has not been developed.

Partial Log of Shaft No. 2, Chicago, Wilmington,
and Vermilion Coal Company, Streator (Geologic
interpretation by the author)

Description of the Strata	Thickness		Depth	
	Feet	Inches	Feet	Inches
Brereton Cyclothem				
26. Coal No. 6				
25. "Slate"	2		2	
24. Fireclay	2	6	4	6
23. Sandstone	6		10	6
22. Slate	1	6	12	
21. "Soapstone"	6		18	
20. Sandstone	2	6	20	6
19. Coal No. 6X		3	20	9
18. Slate	12		32	9
17. Sandstone (Vermilionville) . .	25		57	9
St. David Cyclothem				
16. Blue Granite (?) Niggerhead .	2	9	60	6
15. "Soapstone"	3		63	6
14. Flinty "Soapstone"	5	6	69	
13. Slate	4		73	
12. Sandstone	3		76	
Sumnum Cyclothem				
11. "Slate"	1	6	77	6
10. Coal No. 4	2	6	80	
9. Fireclay	3		83	
8. Sandstone (Pleasantview) . . .	3		86	
Liverpool Cyclothem				
7. Blue limestone (Oak Grove) . .	3		89	
6. "Soapstone" and boulders . . .	15	6	104	6
5. Coal	2	4	106	10
4. Blue shale	14		120	10
3. "Slate"	5		125	10
2. "Soapstone"	21		146	10
1. Coal No. 2	4		150	10

There are two thin cannel coals, neither of them more than four inches thick, in the upper part of the Canton shale member of the St. David cyclothem. These are present wherever the pre-Brereton erosion failed to remove them. At present these beds have no economic importance.

The drift coal (Brereton 6X) assumes economic importance locally. The bed has been worked with open pit and drifts in the river banks east of Kangley at Spring Hill. The thickness of the coal at this horizon is so variable (it is not reported in the Heenanville shaft at all; in the shaft at Streator it is only three inches thick) over short horizontal distances, that with local exceptions it is not likely to be of economic importance.

Streator (No. 6) coal.---The most important in the Streator quadrangle from an economic point of view has been the No. 6 coal.

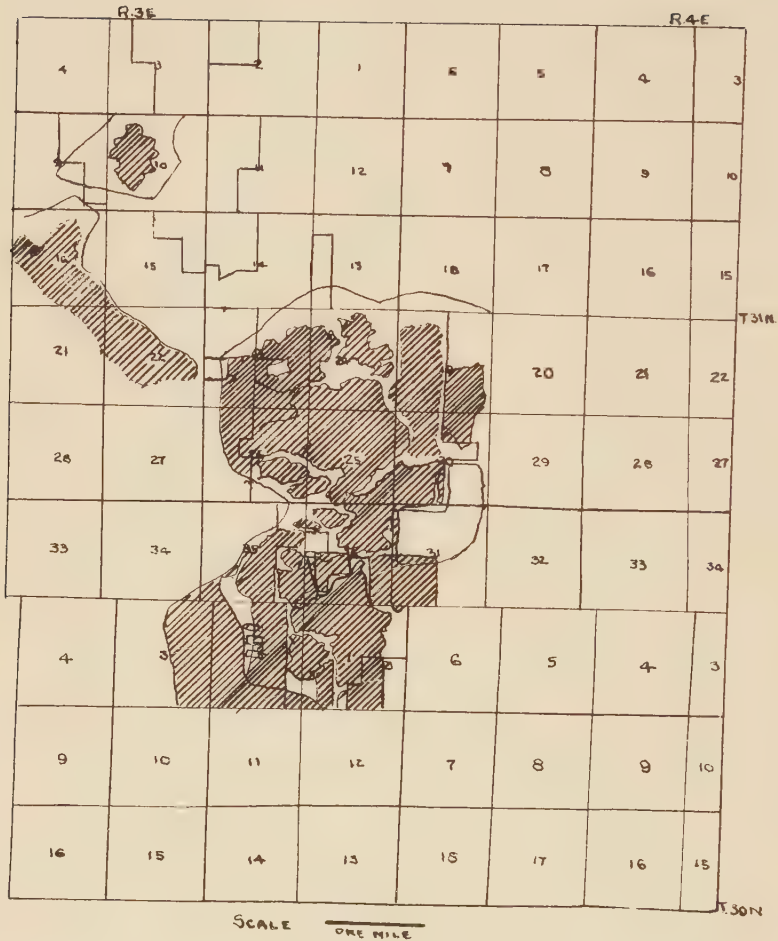


Fig. 6.--Streator Coal Field. Areas where the No. 6 coal has been mined out are indicated by cross hatching.

Today, however, it has been practically worked out. This horizon is considerably more irregular than coal No. 2. According to Dr. G. H. Cady, some of the irregularities in the distribution of this coal are due to pre-glacial erosion.⁶⁶ Other irregularities are due to the topography of the floor--the Vermilionville sandstone thickens and thins from place to place--on which No. 6 coal was deposited.

Just how much of the quadrangle is underlain by the No. 6 coal is uncertain; however, the area is considerably less than that underlain by the No. 2 coal. There are approximately 167 square miles of the quadrangle underlain by the No. 6 coal. The thickness varies considerably. The average thickness in the Streator field is about forty-eight inches, but it is not uncommon to find sections as thick as sixty inches and as thin as thirty-six inches. In the Kangley-Heenanville field it reaches a maximum thickness of 108 inches. In this area, however, it may be that the great thickness of the coal is due to the presence of the drift coal (Brereton 6X) at the bottom of the bed.

Coal No. 6 is particularly well exposed in the vicinity of Streator where it had been uncovered by the stripping at several pits in the vicinity of this city. The pits of the Purington Brick Company and that of the Streator Clay Company to the south of Streator offer excellent exposures of the surface and face of the coal.

TABLE 1
SOUTHEAST CORNER PURINGTON BRICK PLANT QUARRY
NW1/4 NE1/4 SECTION 12, T. 30 N., R. 3 E.

Strata	Feet	Inches
Coal--with lenses of shale and lenses of shaly coal	2	2
Clay		1
Coal		2
Clay--with coaly layers		2
Coal		2-1/2
Clay--with plant remains		3-4
Coal		3
Clay		1-1/2
Coal		2

⁶⁶Ibid., p. 85.

TABLE 1--Continued

Strata	Feet	Inches
Clay		2-1/2
Coal		1/2
Clay		1/2
Coal		1/8
Clay		2
Coal		1
Clay		1-1/2
Coal--films of clay present		4
Coal		6
Underclay--silty, filled with numerous fossils, dove gray, non-calcareous	1	6

TABLE 2

SERRATOR CLAY COMPANY QUARRY, SW1/4 NW1/4 SECTION 7,
T. 30 N., R. 4 E.

Strata	Feet	Inches
Coal	1	8
Clay--flaky, gray to black		3/4
Coal--with clay partings		1-3/4
Clay--gray, flaky, many plant fragments, slickensided, non-calcareous		3
Pyrite		0-3/4
Coal	2	2-1/2
Clay--flaky, gray, hard, coal streaks		4
Coal		3-1/2
Clay--soft, gray, with coaly streaks, irregular lower surface on coal		1-2-1/2
Coal		8

The bed is divided into three benches and each is, in general, mined separately. The upper bench is a relatively clean coal banded with dull and bright layers and containing streaks of mother coal that contain considerable pyrite. The impurities make

up about one per cent of the bench and the bright layers, approximately one-quarter inch thick, make up about one-third of the thickness.

The middle bench contains interbedded clay streaks which are persistent and contain much iron sulphide. There are about six inches of good coal in the middle of the bench.

The lower bench is composed of interbedded clay and coal beds which are persistent throughout the field.

Detailed descriptions of the coal face in some of the mines in the Streator field may be found in Bulletin No. 10, Illinois Geological Survey Coal Mining Investigation, pages 90 to 92.

As far as could be ascertained there are records of only three analyses of samples collected in 1912 from the Chicago, Wilmington, and Vermilion Coal Company Mine No. 3 at Streator. The average of these three analyses is given in the following table:

TABLE 3
ANALYSES OF COAL NO. 6 IN THE STREATOR FIELD*
(AVERAGE CALCULATED FROM DATA OF THREE ANALYSES)
(MINE INDEX NO. 99)

Condition	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B.T.U.
"As Received"	13.56	37.80	40.81	8.11	3.68	10,348
Dry	...	43.73	47.28	8.99	4.26	13,127

*G. W. Hawley, *Analysis of Illinois Coals*, Illinois State Geological Survey Mining Investigations, Bulletin No. 27, 1923, p. 51.

The upper surface of the coal in the Streator field is irregular. There are numerous depressions that vary in size from five to six feet wide, from one foot to two feet deep, and from fifteen to twenty feet long. These depressions have been filled with the roof shale and are called "rolls."

The elevation of the coal varies. Just below the Streator city limits the coal rises on the edge of a basin. This is well shown on the right bank of the Vermilion River in SW1/4 section 23, T. 31 N., R. 3 E., where the coal rises about thirty-five feet in horizontal distance of approximately 150 feet.

Another irregularity was reported from an old mine in section 31, T. 31 N., R. 4 E. The coal is reported to be forty

feet lower in the shaft than it is a short distance to the south.⁶⁷

The floor is locally an underclay several feet thick and, locally, it is composed of a series of fissile shales. The presence of the fissile shale suggests that at these localities coal 6X forms the basal part of this horizon.

The roof of the No. 6 coal in the Streator field is a bluish-gray siltstone that ranges from ten to fifty feet in thickness. The variation in thickness of this siltstone is due in part to erosion and in part to a thickening of this bed to the south and east.

In the Kangley-Heenanville field, to the northwest of the Streator field, is another occurrence of coal No. 6. As in the case of the occurrence in the Streator field, the coal rests locally on an underclay and locally on a fissile shale. In the vicinity of Kangley and as far north as the south side of the Vermilion River at Klein Bridge, the coal is from four to five feet thick. North of the river the coal is from eight to nine feet thick.

The No. 6 coal in the Kangley-Heenanville field is a cleaner coal than the No. 6 in the Streator field. The clay bands are not as numerous nor are they as well developed.

The roof shale is a black flinty shale, locally almost fissile.

This field, structurally, is a trough-like basin that extends northeast-southwest from Heenanville to a point about two miles northwest of Kangley. From the latter point the axis swings southwest through Kangley to Spring Hill. The trough is bounded on the northwest by the thickening of the Vermilionville sandstone and on the southeast by a similar thickening. To the east of Spring Hill it is separated from the Streator field by another ridge developed by the thickening of the underlying sandstone.

The following table is an average analysis of three samples taken from the mine of French Coal Company of Heenanville in 1934.⁶⁸

McLeansboro Coal

Sparland coal No. 7.--At the mouth of Pope Creek in the

⁶⁷Cady, Coal Resources of District I (Longwall), p. 90.

⁶⁸Table appears on page 146.

TABLE 4
AVERAGE ANALYSIS OF THREE SAMPLES TAKEN FROM THE
MINE OF FRENCH COAL COMPANY OF HEENANVILLE
IN 1934*

Condition	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T.U.
"As Received"	12.9	38.2	39.4	9.5	3.62	11,122
Dry	...	43.8	45.2	10.9	4.16	12,766

*Figures from the Illinois Geological Survey Coal Division.

north central part of section 18, T. 30 N., R. 4 E., there is an abandoned strip mine from which a coal, which is correlated in this report as the Sparland No. 7 coal, was extracted. The same coal outcrops along the left bank of the Vermillion River at several places in the same section. Farther south the same horizon outcrops in sections Nos. 13, 14, 15, and 16. The floor is an underclay and the roof is a non-gritty shale except where, locally, the overlying sandstone rests directly upon the coal.

The coal is in general a hard, clean, bright coal. The areal distribution of this coal is not known and there are no records of any wells that have penetrated the horizon. Except where stripping is feasible, as at the mouth of Pope Creek, this is of doubtful economic value.

As far as could be ascertained no analyses have been made of this coal.

Coal Mining

The method of mining most commonly used in this area was the type that gave the district its name, to wit, the "Longwall." The thick bed at Heenanville, however, was mined by the "Room and Pillar" method and today some of the smaller mining operations consist of robbing the pillars of the old mines.

Today, however, the Longwall method has been abandoned and the Room and Pillar method is the type of mining used in the numerous "wagon mines" of this area. This latter method of extraction is also used in the only mine in the area which is working the No. 6 at Heenanville.

Strip and open pit mining has been used to advantage in the vicinity of the Vermillion River where overburden has been sufficiently removed by erosion to permit access to the coal. Open

pit methods have also been used in the floors of the clay pits in the vicinity of Streator where the overburden has been removed for the manufacturing of clay products.

All the coal produced is used as fuel locally for the greenhouses, schools, and other public buildings, and for domestic heating.

Shale, Siltstone, and Clay

Shale

There are no shales of economic importance in the Streator quadrangle. The shale above the No. 2 coal in the vicinity of Lowell is used for the manufacture of common brick and it is possible that this horizon might be useful in the northwestern part of the Streator quadrangle.

Siltstone

The Brereton siltstone, which lies between the Streator (No. 6) coal and the Brereton limestone, is the only horizon that is used at the present for the manufacture of ceramic products. It is a thick, bluish gray siltstone, generally free from sand except in the upper part. Concretions, some of them one to two feet in diameter, are scattered through the formations and at some horizons are numerous.

Several good exposures of this siltstone are to be found along the Vermilion River in SE1/4 section 9, T. 31 N., R. 3 E. Other exposures are along the cliffs of the Vermilion River from the southwest corner of section 23, T. 31 N., R. 3 E. as far upstream as the reservoir dam in the NE1/4 section 12, T. 30 N., R. 3 E.

A number of ceramic plants are exploiting this siltstone in the vicinity of Streator, namely: Streator Brick Company, Streator Clay Products Company, Streator Drain Tile Company, and Purington Brick Company.

Clay

The clay below the La Salle coal (No. 2) is worked at Lowell. A sample from the same horizon in the Chicago, Wilmington, and Vermilion Coal Company mine No. 2 at Streator has been tested and is reported to be refractory clay and suitable for the manufacture of paving brick.⁶⁹ This clay, however, is not accessible

⁶⁹ Ross C. Purdy and F. W. DeWolf, Yearbook of 1906, Illinois State Geological Survey, Bulletin No. 4, 1907, p. 165.

and probably will not be available until mining operations on the No. 2 coal are resumed.

The underclay of the Streator (No. 6) coal in the Purington Brick Company Quarry is mixed with the siltstone to produce a proper mixture for the products manufactured by this company.

At the mouth of Pope Creek in the NE1/4 section 18, T. 30 N., R. 4 E., the underclay of the No. 7 coal was mined and mixed with Brereton siltstone to produce a satisfactory raw material for the Streator Clay Products Company. A ten-foot section of this clay is exposed on the left bank of the Vermillion River in the NW1/4 section 18, T. 30 N., R. 4 E., but there are several calcareous horizons in the clay at this station and the overburden is too thick to permit stripping. Underground mining operations would be necessary to exploit this clay at this locality.

The pebbles and boulders in the glacial till sheets make them unsuitable for ceramic purposes. The till sheets are, in general, thin and the carbonate content high. These tills might be used for manufacturing common brick and tile but they have never been tested and their value is doubtful.

Ceramic Plants

Streator Brick Company.--The plant of the Streator Brick Company is located in Streator in the central part of SE1/4 section 35, T. 31 N., R. 3 E. The pit of this company is located just to the north of the plant. The Brereton siltstone is exploited and the working faces expose about twenty feet of the siltstone overlain by ten to twelve feet of glacial till, outwash, and silt. The overburden is stripped and discarded. The siltstone is excavated by power shovels and loaded cars are hauled to the plant by electric motors.

The company operates several intermittent kilns and two continuous kilns. The plant produces ordinary building brick, face brick, and brick made to special specifications. A one-mile spur to the Wabash Railroad and the Santa Fe Railroad furnishes transportation facilities.

Streator Drain Tile Company.--The plant of the Streator Drain Tile Company is located one-quarter of a mile to the west of the Streator Brick Company plant, in the SW1/4 section 35, T. 31 N., R. 3 E. The company operates a quarry in the Brereton

siltstone in the NW1/4 section 2, T. 30 N., R. 3 E. about one mile south of the plant.

In the quarry the working face exposes fifteen to twenty-five feet of siltstone overlain by ten feet of glacial till and silt. The overburden is stripped and discarded. The siltstone at this locality contains numerous concretions which are separated from the siltstone at the plant. The excavating is done by gasoline shovels and the loaded cars are drawn over a mile of narrow gauge track by a gasoline motor.

The company operates several intermittent kilns and the plant produces sewer pipe and drain tiles.

The same spur that serves the Streator Brick Company affords an outlet for this organization.

Purington Brick Company.--The plant of the Purington Brick Company, formerly the Barr Brick Company, is located on the south line of the SW1/4 section 1, T. 30 N., R. 3 E., about one mile south of Streator.

The Brereton siltstone is exploited here; the pit is located in the NE1/4 section 12, T. 30 N., R. 3 E. and is overlain by Pleistocene deposits (Geologic section No. 10). The overburden is discarded but at this plant the sandy phase of the siltstone, the siltstone, and the Vermilionville sandstone are all mixed to furnish a satisfactory raw material. The No. 6 coal is used as fuel in the plant.

The excavating is done by electric shovels and the cars are hauled within one-eighth of a mile of the plant by motor. A cable system is used to move the cars the rest of the distance.

The plant is the largest in the district, operating many kilns and producing building and paving brick. A spur, one and one-quarter miles long, from the Wabash Railroad, serves as an outlet for this plant.

Streator Clay Products Company.--The plant of the Streator Clay Products Company is located about one mile southeast of Streator in the southwest corner of section 6 and in the northwest corner of section 7, T. 30 N., R. 4 E.

The pits operated by this company lie directly to the south and are in the Brereton siltstone. There is exposed, in the working face, about fifty feet of siltstone overlain by ten to twenty feet of overburden. The overburden is thicker at the south end of the pits. This, as well as the sandy, upper twenty feet of siltstone, is discarded.



Fig. 7.--Gravel pit in 600-foot delta, NW1/4 SE1/4 section 5, T. 31 N., R. 3 E.



Fig. 8.--Purington Brick Company pit, NW1/4 NE1/4 section 12, T. 30 N., R. 3 E.

The excavating is done by power shovels and the cars are moved on the floor of the pits by motor. Haulage from the pits to the plant is done by a cable system.

The company operates several intermittent kilns and produces brick and sewer pipe. A one-half mile spur from the Wabash Railroad furnishes transportation.

Sand and Gravel

There are no extensive deposits of commercial sand and gravel in the Streator quadrangle. There are numerous small deposits, all of which are Pleistocene in age, present in glacial outwash, kames, and Kankakee Torrent deposits.

In the northern part of the quadrangle in section 5, T. 31 N., R. 3 E. there are several delta deposits, of rather small, well sorted gravels, developed where outwash from the Farm Ridge ice drained into Lake Illinois. These gravels have been used extensively for road surfacing and, locally, in the manufacturing of concrete.

In the SE1/4 section 23, T. 32 N., R. 2 E., and in the SW1/4 section 19, T. 30 N., R. 4 E. two pits were opened in Lake Illinois deposits which were apparently laid down in pre-Cropsey times. The northern pit is small and the gravels have been used locally for surfacing roads. The southern pit is now abandoned.

Deposits of well rounded gravels occur along Otter Creek in sections 16, 17, 18, 19, 20, and 21, T. 31. N., R. 4 E. The Cephas Williams Gravel Company has installed a washing plant in section 19 and is furnishing gravel for road and concrete work. These gravels are, apparently, outwash materials from the Chatsworth ice.

There are several gravel bars in the northwest part of the quadrangle which seem to be the result of deposition by the Kankakee Torrent. One of the bars in section 23, T. 32 N., R. 2 E. has been opened and it consists of well sorted and well rounded gravels. The gravel forming this deposit has been used locally for road surfacing.

TABLE 5
GRAVEL AND SAND DATA*

Sample Number Sieve Analysis	Mesh Size	308	504	508
		Per Cent Passing		
	2	100	100	93
	1-1/2	96	98	90
	1	96	94	83
	3/4	91	92	78
	1/2	88	89	72
	3/8	84	84	65
	4	75	71	47
	8	61	53	30
	16	39	33	15
	20	28	24	10
	50	6	5	2
	100	1	1	1
Clay content (per cent)		4.3	12.9	5.0
Weight of cubic foot of aggregate.....		119.50	113.39	115.98
Specific gravity (sand)		2.69	2.65	2.69
Specific gravity (gravel)		2.61	2.48	2.61
Wear, per cent (sand)		4.2	8.0	4.6
Absorption, per cent (gravel)		2.0	3.73	1.8

*Data from Illinois Geological Survey.

Remarks:

Number 308.--Abandoned gravel and sand pit two hundred yards long with twenty foot face. Boulders up to two feet in diameter fairly numerous.

Gravel: Siliceous material and dolomitic limestone. Small percentage of chert, some disintegrated granite, limonite and cemented material. Trace of soft material and ochre.

Sand: Siliceous material. Large per cent of quartz and small per cent of chert and dolomitic limestone. Trace of ochre, limonite and soft materials.

TABLE 5--ContinuedRemarks:

Number 504.--Pit two hundred yards long with nine-foot face. Chiefly gravel.

Gravel: Mainly siliceous material, some dolomitic limestone. Small per cent of chert, ochre, and light flat particles.

Sand: Mainly siliceous material. Some dolomitic limestone, small per cent of quartz, chert, ochre, and soft materials.

Number 505.--Pit twenty-five yards long with fourteen-foot face. Very little sand.

Gravel: Mainly siliceous materials. Some cemented fragments, limonite, chert, and soft material.

Sand: Mixed siliceous material. Small per cent of quartz, traces of chert and soft material.

Location:

Number 308--Left bank of the Vermilion River, SW1/4 section 19, T. 30 N., R. 4 E., Livingston County. Sample from pit face.

Number 504--NW1/4 section 20, T. 31 N., R. 4 E., La Salle County. Sample from pit face.

Number 505--SE1/4 section 23, T. 32 N., R. 2 E., La Salle County. Sample from pit face.

Soils

The most important economic resource of the Streator quadrangle is the soil. The present soils have been formed from loess, till, slope wash, and alluvial deposits.

The variety and distribution of the various types of soil of La Salle and Livingston Counties has been mapped in detail.⁷⁰

The soils of the quadrangle have been classified as follows:

Upland Prairie Soils:

Brown Silt Loam

Black Clay Loam

Black Silt Loam

Brown Silt Loam on Tight Clay

⁷⁰Cyril J. Hopkins, J. G. Mosier, J. H. Pettit, and J. C. Readhimer, La Salle County Soils, University of Illinois Experiment Station Soil Report No. 5, 1913; J. G. Mosier, S. V. Holt, F. A. Fisher, E. E. DeTurk, and H. J. Snider, Livingston County Soils, University of Illinois Experiment Station Soil Report No. 25, 1923.

Brown-gray Silt on Tight Clay

Upland Timber Soils

Yellow-gray Silt Loam

Yellow Silt Loam

Terrace Soils

Yellow-gray Silt Loam over Gravel

Yellow-gray Sandy Loam over Gravel

Brown Sandy Loam over Gravel

Swamp and Bottom-land Soils

Mixed Loam (small streams)

Medium Peat on Clay

Deep Peat

Upland Prairie Soils

The most extensive as well as the most valuable type is the brown silt loam. This soil is formed from wind-blown, loess-like material and is distributed over most of the quadrangle. The surface soil is a brown silt loam, varying on one hand to black as it grades into black clay loam or black silt loam, and on the other to grayish brown or yellowish brown as it grades into the timber types.

Where erosion has removed part of the loessial materials, glacial till is found close to the surface giving rise to a somewhat inferior soil.

Upland Timber Soils

The essential difference between the Prairie and Timber soils is that the latter contains less organic matter. This fact also accounts for the black or brown color of the prairie soils and the yellow or gray color of the timber soils.

Yellow-gray silt loam.--This type is concentrated on the uplands along the larger streams of the area. The upper part of the soil is gray, yellowish, gray or brownish silt loam.

Yellow silt loam.--This soil is also found along larger streams. The surface soil is a yellow silt loam varying to a grayish yellow.

These upland timber soils are for the most part in wood lots or in pastures and should not be cultivated except where slopes are gentle.

Terrace Soils

The terrace soils were apparently formed during the melt-

ing of the glacier. Sands and gravels were deposited, later trenched so deeply that the terraces were no longer flooded at times of overflow, and the benches left were covered with finer materials which form the present soils. The value of these soils depends on the depth to the underlying sand or gravel. If the underlying material is too near the surface crops may suffer during protracted periods of dry weather.

These terrace soils are restricted to the Vermilion River valley and its tributary valleys. All the terrace soils described⁷¹ are acidic and low in plant food.

Swamp and Bottom-land Soils

The soils that belong to this group include the bottom lands along the streams and the soils of the poorly drained areas.

Mixed loam.--The soil that has developed along the flood plains of the Vermilion and its tributaries is a mixed loam. It occurs in irregular strips, rarely more than a quarter of a mile wide, and is a mixture of types. Any effort to indicate the variations that might be present at a given station would be useless because the next flood would leave a different mixture.

Deep peat.--This type is found in a small area in section 27, T. 32 N., R. 2 E. The surface soils, from one to six and two-thirds inches, are a brown peat; the subsurface is composed of a brown peat which persists to a depth of forty inches.

Medium peat on clay.--This type of soil occurs in an area of about eighty-three acres surrounding the area of deep peat described above.

The upper six inches consist of thoroughly decomposed peat sixteen to twenty inches thick.

The area occupies a depression which drained and is now under cultivation.

Water Supply

Possible Water-bearing Formations

Cambrian system.--The Mt. Simon and the Dresbach are prolific aquifers. The deep wells at Streator obtain water from these horizons. The water from the Dresbach has, as a rule, fewer dissolved solids than has the water from any other widespread

⁷¹Ibid., pp. 22-25.

aquifer in the northeastern part of Illinois.⁷²

Ordovician system.--The St. Peter sandstone furnishes considerable water. In general the water is too salty for domestic use but several of the factories at Streator are using water from this horizon. Wells in this formation are usually completed after the base of the sandstone has been reached, which is at a depth of from five hundred to seven hundred feet. The wells are cased through the Pennsylvanian system, about 200 to 225 feet.

The wells do not flow but the water stands within one hundred feet of the surface of the ground and yields from thirty to one hundred gallons per minute are obtained.

The water is strongly sulphurous and contains a large amount of sodium salts. It is reported to cause considerable foaming when used in boilers.⁷³

The Galena-Platteville formation contains some lenticular porous zones of dolomitic sandstone. These may yield water, but as the formation contains considerable pyrite any water encountered is likely to be highly charged with sulphates.

Pennsylvanian system.--Although there are numerous water-bearing horizons in the Pennsylvanian system, prospecting for potable water in this group is not recommended if other sources are available. Except near the outcrop where the soluble materials have been removed the waters, due to the presence of large amounts of pyrite and organic materials, contain sulphates, salts, and hydrogen sulphide in quantities sufficient to render the water unfit for most uses.

Pleistocene system.--The principal water horizons that occur in the Pleistocene formations of the quadrangle are the sands and gravels deposited in Lake Illinois and later covered by Cropsey till, the lenticular zones of sand and gravel in the various till sheets and outwash material from the various ice stands, particularly that from the Farm Ridge and Chatsworth ice sheets.

City Water Supplies

The city of Streator obtains its water supply from the Vermilion River although some of the factories obtain water from the St. Peter sandstone. The river water is treated in a

⁷²C. B. Anderson, The Artesian Water of Northeastern Illinois, Illinois State Geological Survey, Bulletin No. 34, 1919.

⁷³Ibid., p. 204.

purifying plant before it is sent into the city mains.

The village of Grand Ridge obtains its water from a well 160 feet deep in glacial drift.

Log of Village Well at Grand Ridge

Description of Strata	Thickness Feet	Depth Feet
Clay, yellow	3	3
Clay, blue	7	10
Sand, no water	105	115
Sand and gravel (water)	35	160

It is reported that the sand and gravel encountered at 150 feet extends to 195 feet and rests on blue clay which extends at least 250 feet.

The well was drilled in 1914 and on completion the water level stood within thirty-five feet of the surface. No lowering of the water was noted after a twenty-two-hour test of pumping seventy gallons to the minute.

The water has low mineral content and is suitable for boiler use.

The village of Long Point is obtaining water from a deep well that has penetrated 150 feet into the St. Peter.

The other villages throughout the quadrangle are supplied by privately owned shallow wells that derive water from the Pleistocene formations.

Farm Wells

The principal source of water for most of the farm wells in the quadrangle are the Pleistocene deposits.

In the southern half of the quadrangle the wells are dug wells, twenty-five to fifty feet deep. The sands and gravels deposited in Lake Illinois prior to the advance of the Cropsey ice apparently serve as the aquifer.

In the area along the east, west, and north portions of the quadrangle where the till sheets are thick, due to the presence of terminal moraines, the wells are deeper and some water is obtained from sand and gravel lenses in the drift.

There are few drilled wells in the western part of the quadrangle from which water is obtained from aquifers below the Pennsylvanian series.

Springs

Springs occur locally where streams have cut through Pleistocene deposits and have exposed sand and gravel resting on an impervious till. Such a situation is well developed along the left bank of the Vermilion River in sections 30, 31, and 32, T. 32 N., R. 3 E. and sections 5 and 6, T. 31 N., R. 3 E. All the farms located along the river in these sections use these springs as a water supply. The largest spring in the quadrangle is developed in a similar situation on the left bank of the Vermilion River in section 19, T. 30 N., R. 4 E. This spring is utilized as a source of water by the many permanent camps located along the river.

Surface Water

As stated above, the city of Streator utilizes the Vermilion River. In addition many streams are ponded by the construction of low dams and the collected water used for watering stock.

TABLE 6

THE MINERAL ANALYSIS OF UNDERGROUND WATERS FROM WELLS IN THE STREATOR QUADRANGLE						
TOWN	GRAND RIDGE	STREATOR	STREATOR	STREATOR	STREATOR	STREATOR
OWNER	VILLAGE	WESTERN GLASS CO.	VULCAN GETTINGING CO.	STREATOR PAVING BRICK CO.	CITY	CITY
	WATERWORKS			(BRICK PLANT)	CITY PARK	WATER FROM VERMILION RIVER
DEPTH OF WELL IN FEET	160	540	563	660	24.96	
DEPTH OF CASING IN FEET	146 PLUS 1497. SCREEN	....	200	....	....	(AVERAGE OF 12 MONTHLY ANALYSES)
RATE OF PUMPING GAL. PER MIN.	110	60	60	....	FLOWES(?)	
DATE OF SAMPLE	7-5-15	10-31-11	10-31-11	10-31-11	10-31-11	
DETERMINATIONS MADE (PARTS PER MILLION)						
POTASSIUM	3.0	26.3	49.0	49.7	346.8	18.0
SODIUM	63.4	192.5	312.2	300.7	3732.0	18.0
AMMONIUM	1.8	.9	1.1	1.5	5.0	....
MAGNESIUM	13.7	11.9	8.8	23.9	143.3	29.0
CALCIUM	24.7	48.9	61.8	56.0	693.3	53.0
IRON	.9	.2	.3	TRACE	6.3	.2
ALUMINA	1.0	44.0	TRACE	TRACE	10.0	.0
NITRATES	.0	.0	.0	.0	.0	.0
NITRATES	1.4	5.8	.9	.5	.2	12.0
CHLORINE	7.0	210.0	410.0	410.0	7100.0	6.9
SULPHATE	.0	61.6	21.7	62.1	403.2	68.0
SILICA	7.2	9.6	12.8	10.0	12.0	14.0
HYDROGEN SULPHIDE	.0	14.5	15.0 (EST)	15.0	....	....
MANGANESE	.04	.0	....	....	....	....
BASES	.0	.0	.0	.0	.0	.0
HYPOTHEetical COMBINATIONS						
	MTS. PER MILLION	GRS. PER GALLON	PTS. PER MILLION	GRS. PER GALLON	PTS. PER MILLION	GRS. PER GALLON
POTASSIUM NITRATE	....	....	....	....	....	....
POTASSIUM NITRATE	2.3	.13	9.5	.55	1.5	.09
POTASSIUM CHLORIDE	4.0	0.23	43.1	2.51	92.2	5.38
POTASSIUM SULPHATE	....	....	....	....	....	....
SODIUM NITRATE	....	....	....	....	....	....
SODIUM CHLORIDE	8.4	.49	312.7	18.24	604.3	35.25
SODIUM SULPHATE	....	....	91.2	5.32	32.1	1.88
SODIUM CARBONATE	132.3	8.07	82.1	5.38	146.4	8.54
AMMONIUM NITRATE	....	....	....	....	....	....
AMMONIUM CHLORIDE	....	....	....	....	....	....
AMMONIUM CARBONATE	4.9	.29	1.7	.27	2.9	.17
MAGNESIUM NITRATE	....	....	....	....	....	....
MAGNESIUM CHLORIDE	....	....	....	....	....	....
MAGNESIUM SULPHATE	....	....	....	....	....	....
MAGNESIUM CARBONATE	47.4	2.76	41.2	2.4	23.6	1.37
CALCIUM CHLORIDE	....	....	....	....	....	....
CALCIUM SULPHATE	....	....	....	....	....	....
CALCIUM CARBONATE	61.7	3.6	122.1	7.13	184.3	9.0
IRON CARBONATE	11.9	.11	.4	.02	.6	.03
ALUMINA	1.0	.06	44.0	2.57	Ta.	Ta.
SILICA	7.2	.42	9.6	.56	12.8	.75
MANGANESE CARBONATE	1.1	.01	....	....	....	....
BASES	.5	.03	....	....	....	....
TOTAL	277.7	16.2	770.6	44.95	1070.7	62.46

